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Study on Infrastructure Developments of Mobile Generations

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ABSTRACT

Nowadays, as Mobile communication systems have been developing in various ways, people can get better communications and mobility. A long way in a remarkably short time has been achieved in the history of wireless. The first generation (1G) has fulfilled the basic mobile voice while the second generation (2G) has introduced capacity and coverage. This is followed by the third generation (3G), which has requested data at higher speeds to open the gates for truly "mobile broadband" experience. Furthermore, the fourth generation will be realized as the next generation. 4G provides access to a wide range of telecommunication services, including advanced mobile services, supported by mobile and fixed networks, which are increasingly packet-based. This paper explains about the required components of infrastructure in mobile generations (from 1G to 4G) and also describes the performance of each portion in evolutions of 1G to 4G infrastructure. And then, people can study the introduction of the infrastructure requirements of 5G network technology.

KEYWORDS: *1G, 2G, 3G, 4G, infrastructure, evolution*

I. INTRODUCTION

The first generation (1G) mobile wireless communication network was analog used for voice calls only. The second-generation (2G) is a digital technology and supports text messaging. The generation (3G) mobile technology provided higher data transmission rate, increased capacity and provide multimedia support.

The fourth-generation (4G) integrates 3G with fixed internet to support wireless mobile internet. In this paper, people can look at the infrastructure and components that underpin each of these mobile technologies. Infrastructure of First Generation (1G) contains the mobile station (MS), base station or base transceiver station (BTS), mobile switching center (MSC), and voice service. The infrastructure of Second Generation (2G) or GSM comprises the mobile station, base transceiver station, base station controller (BSC), mobile switching center (MSC), voices and message services. The infrastructure of 2.5G (GPRS) includes mobile station, base transceiver station, base station controller, mobile switching center, serving gateway support node (SGSN), and gateway GPRS support node (GGSN), voices, messages and data services. The infrastructure of third-generation (3G) involves mobile station, base station or Node-B, radio network controller (RNC), mobile switching center, SGSN, GGSN, voice, message, high-speed data and multimedia connectivity services. The infrastructure of fourth-generation 4G comprises mobile station, ENode-B, mobility management entity (MME), a serving gateway (S-GW), PDN-gateway (PDN-GW), voice, data and the other services.

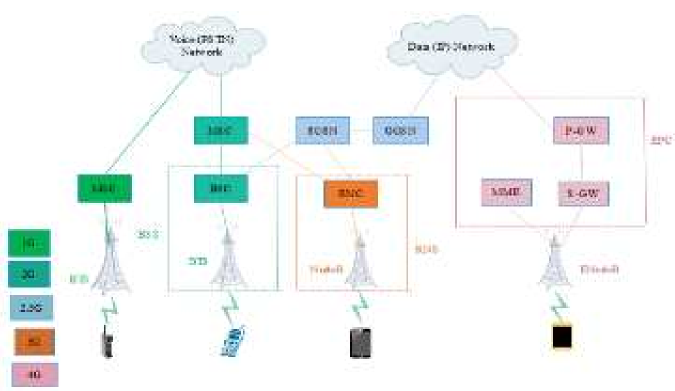

Fig 1: Overall Infrastructure of Mobile Generations

II. REQUIRED COMPONENTS OF INFRASTRUCTURE

The infrastructure of mobile generations requires many components to achieve the services for the users. The components are mobile station (MS), base transceiver station (BTS), base station controller (BSC), mobile switching center (MSC), and public switched telephone network (PSTN) or services.

A. Mobile Station (MS)
A mobile station (MS) comprises all user equipment and software needed for communication with a mobile network. This means that a mobile phone or mobile computer connected using a mobile broadband adapter. A mobile station includes mobile equipment (ME) and a subscriber identity module (SIM). Mobile Equipment is identified by an IMEI (international mobile equipment identity). The ME forms part of the mobile termination (MT) which depending on the application and services, may also include various types of terminal equipment (TE) and associated terminal adapter (TA). SIM is used to support roaming. SIM contains the International Mobile Subscriber Identity (IMSI). The functions of the mobile station are a voice and data transmission, frequency and time synchronization, monitoring of power and signal quality of the surrounding cells, and provision of location updates even during inactive state [1].

B. Base Transceiver Station (BTS)
A base transceiver station (BTS) is equipment that facilitates wireless communication between user equipment (UE) and a network. BTS can be applicable to any of the wireless communication standards; it is generally associated with mobile communication technologies like GSM, and CDMA. Antennas may also be considered as components of BTS in general sense as they facilitate the functioning of BTS.

C. Base Station Controller (BSC)
A base station controller (BSC) is a critical mobile network component that controls one or more base transceiver stations (BTS), also known as a base station or cell sites. Key functions of BSC include radio network management (such as radiofrequency control), BTS handover management and call setup [2].

D. Mobile Switching Center (MSC)
A mobile switching center (MSC) is the centerpiece of a network switching subsystem (NSS). The MSC is mostly associated with communications switching functions, such as call set-up, release, and routing. However, it also performs a host of other duties, including routing SMS messages, conference calls, fax, and service billing, as well as interfacing with other networks, such as the public, switched the public switched telephone network (PSTN).

The MSC works with a large database known as the home location register (HLR), which stores relevant location and other information for each mobile phone. Because accessing the HLR uses many network resources, most operators employ visitor location registers (VLRs). These are relatively smaller databases, which are integrated with the MSC [2]. The parts of services contain the PSTN (public switched telephone network) and PDN (public data network) or IP (internet protocol).

III. DEVELOPMENTS OF MOBILE NETWORK INFRASTRUCTURE
With the rapid development of wireless communication networks, mobile operators need to build entirely new networks and license entirely new frequencies. Mobile operators use many technologies to deliver higher-speed data services.

A. First Generation Technology (1G)
Those circuit-switched systems were based on analog transmission techniques and were designed to carry low-quality voice traffic. First-generation of wireless telecommunication technology consists of various standards among which most popular were Advance Mobile Phone Service (AMPS), Nordic Mobile Telephone (NMT), and Total Access Communication System (TACS). All of the standards in 1G use frequency modulation techniques for voice signals and all the handover decisions were taken at the Base Stations [3][4].

Mobile first-generation infrastructure is described in Fig 2. In that infrastructure includes many components such as mobile station (MS), base transceiver station (BTS), mobile switching center (MSC), and the public switched telephone network (PSTN).PSTN also is known as the plain old telephone system (POTS) is basically the inter-connected telephone system over which telephone calls are made via copper wires. The PSTN is based on the principle of circuit switching. Therefore, when a call is made a particular dedicated circuit activates which eventually deactivates when the call ends. Telephone calls transmit as analog signals across copper wires [1].

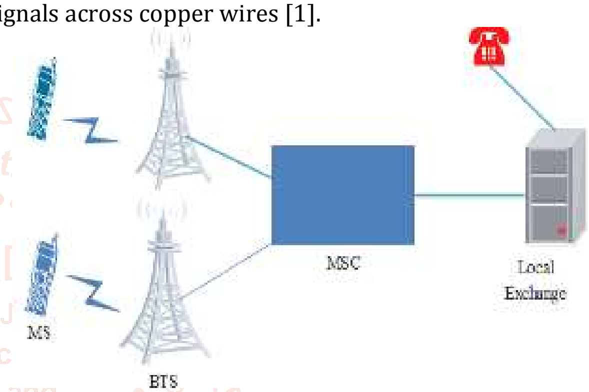

Fig 2: First Generation (1G) Infrastructure

B. Second Generation Technology (2G) or GSM
Second Generation technology was introduced in the early 1990s. The second generation of mobile communication system introduced a new digital technology for wireless transmission also known as Global System Mobile communication (GSM). GSM technological backbone of choice is TDMA (similar to FDMA). The radio frequency band utilized by GSM is the 900MHz spectrum and later introduced on the 1800MHz band. GSM technology was capable of supporting up to 14.4 to 64kbps (maximum) data rates which are sufficient for short message services (SMS) and multimedia message services (MMS) [4].

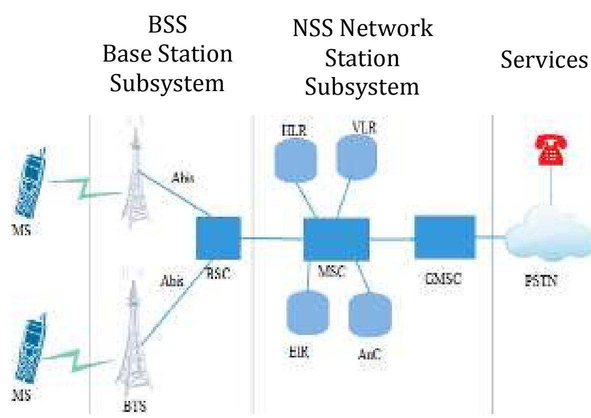

Fig 3: GSM (2G) Infrastructure

A network mobile system has two major components: the fixed infrastructure (network) and mobile subscribers, who

use the services of the network. The fixed installed network can again be subdivided into three sub-networks: radio networks, mobile switching network and management network.

According to Fig 3, the 2G system can be divided into four parts. They are

- Mobile Station (MS)
- Base Station Subsystem (BSS)
- Network Station Subsystem (NSS)
- Part of Services [4].

A mobile transmits and receives messages to and from the GSM system over the air interface to establish and continue connections through the system. It provides the voice, message, and data services for the users [2].BSS contains all nodes and functionalities that are necessary to wirelessly connect mobile subscribers over the radio interface to the network. The radio interface is usually also referred to as the 'air interface'. BSS comprises the Base Station Controller (BSC) and the Base Transceiver Station (BTS) [4].

Home Location Register (HLR) is the central database which provides information about the mobile phone subscribers who are authorized to use GSM network. Other data which are stored in the HLR database are GSM services, that the subscriber has requested or been given, current location information and call divert services [4].

VLR is the database which provides information about the mobile phone subscribers who are using roaming services. The data which are stored in the VLR is either received from the HLR or collected from the mobile station. In general, there is one central HLR per public land mobile network (PLMN) and one VLR for each MSC [4].

In order to support data rate, General Packet Radio Service (GPRS) was designed as a packet-switched addition to the circuit-switched GSM network in 2001. It should be noted that IP packets can be sent over a circuit-switched GSM data connection as well. The outcome was 2.5G networks which differentiated from their predecessors as they could support packet data services in addition to the circuit-switched data services that 2G used to support [5].

EDGE (Enhanced Data Rate for GSM Evolution) is the technology for the enhanced GPRS or EGPRS and could increase GSM and GPRS data rates up to 3 times. This could be done by using different modulation techniques which can provide data rates up to 384kbps [5].

C. Third Generation Technology System (3G)

The ever-growing needs of subscribers and the several technological advances that existed in the early 2000s made Second Generation Systems obsolete. The development of the third generation technology which focused on the improvement of voice services with some data capabilities. The International Telecommunication Union (also known as ITU) has defined 3G systems as being capable of supporting high-speed data ranges of 144 kbps to greater than 2 Mbps. A few technologies are able to fulfill the International Mobile Telecommunications standards (IMTS), such as universal mobile telecommunication system (UMTS), code division multiple access (CDMA) and some variation of GSM such as EDGE. UMTS network consists of four parts: the ME (mobile equipment), UTRAN (the UMTS Terrestrial Radio Access Network), CN (Core Network) and the part of Services [4].

D. Mobile Equipment of UMTS Network in 3G

TheUE (User Equipment) or ME (Mobile Equipment) contains the mobile phone and the SIM (Subscriber Identity Module) card called USIM (Universal SIM) which contains member specific data and enables the authenticated entry of the subscriber into the network. This UMTS UE is capable of working in three modes: CS (circuit-switched) mode, PS (packet-switched) mode and CS/PS mode. In the CS mode, the UE is connected only to the core network. In the PS mode, the UE is connected only to the PS domain (though CS services like VoIP (Voice over Internet Protocol) can still be offered), while in the CS/PS mode, the mobile is capable of working simultaneously to offer both CS and PS services [4].

E. Radio Access Network of UMTS

The components of the UMTS Terrestrial Radio Access Network (UTRAN) are Node B and Radio Network Controller (RNC).

F. Base Transceiver Station or Node-B of UMTS Network in 3G

The base station is called Node-B in the 3GPP (third generation partnership project) standards, which is responsible for all functions required for sending and receiving data over the air interface. Node-B is also responsible for the power control of all connections. The other functions of the base station or Node-B are physical channel coding, modulation, demodulation, and error handling [4].

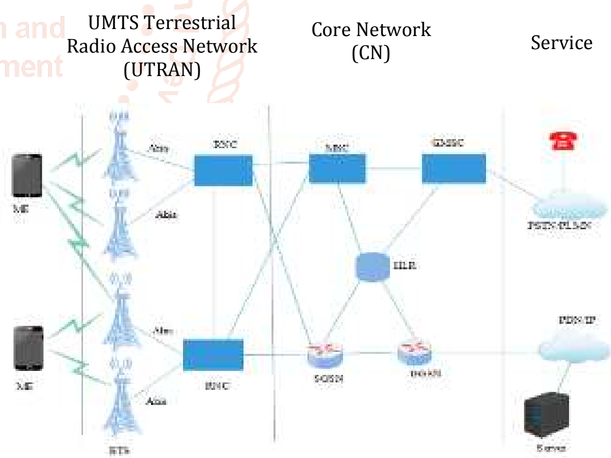

Fig 4: UMTS Infrastructure

Even Third Generation Systems failed to meet user's expectations as there were limitations mainly on access speed. That led the industry to find ways to update the already existing air interface standards and replace them with improved and higher data versions.HSPA or High-Speed Packet Access which is the evolved version of W- CDMA is the actual technology for 3.5 Network Generation [4].

G. Fourth Generation Technology System (4G)

In the 2010s, Fourth Generation (4G) is also known as Long Term Evolution (LTE).4G is IP-based and packet-switching evolution of 3G systems. A 4G system in addition to voice, data and the other services Third Generation Systems support, provides mobile broadband internet access.

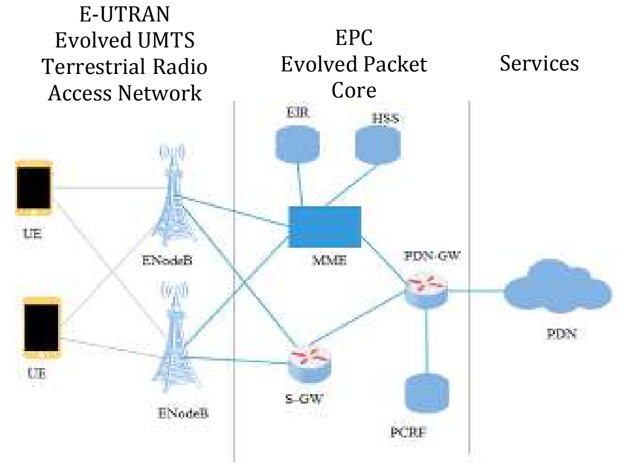

Fig 5: 4G Network Infrastructures

The LTE Network Infrastructure consists of three parts: the E-UTRAN which stands for the evolved UMTS Terrestrial Radio Access Network, the EPC or Evolved Packet Core and the part of Services [4].

LTE network infrastructure contains three parts; evolved UMTS terrestrial radio access network (E-UTRAN), evolved packet core (EPC) and part of services.

E-UTRAN or Evolved UMTS Terrestrial Radio Access Network is the air interface of the Fourth Generation Network System and it is the replacement of UMTS and HSPA technologies that were specified in 3GPP networks. It consists of UEs or User Equipment which is the devices through which the user is connected to the network and the ENode-B which are the Evolved versions of Node-B [4].

IV. EVOLUTIONS OF MOBILE GENERATIONS

The evolution and comparison of infrastructures for mobile generations are described in this article by the author's view.

A. Evolution of 1G to 2G

In the author's view, the radio signals used by 1G networks are analog while 2G networks are digital. 1G gives only voice services but 2G can give not only voice services but also message services. Evolved 2G can also support data services. In 1G, MSC (mobile switching center) is the part of the cellular network and used to call routing, registration, authentication. In 2G, MSC used to control it's under BSC and to update the information of the mobiles.2G has also GMSC (gateway MSC) which serves as a gateway. GMSC can communicate to different networks.2G has been adapted to the GPRS connectionless packet mode of operation. A new functional node called the packet control unit (PCU) has been introduced to control and manage the allocation of GPRS radio resources to mobile users.

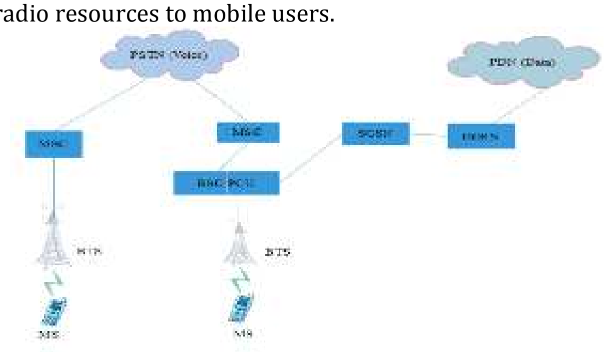

Fig 6:1G and 2G Infrastructure

B. Evolution of 2G to 3G

Base transceiver station (BTS) of 2G is responsible for transmitting and receiving radio signals while this BTS is advanced to Node-B in 3G. When the BSC (base station controller) handles the allocation of radio channels and controls handovers from BTS to BTS, this BSC is upgraded to the radio network controller (RNC) in 3G. Security of RNC in 3G is better than 2G. While MSC of 2G is responsible for routing all the voice or message services, GMSC (gateway MSC) of 3G is used to route calls outside the mobile network. When the SGSN (serving gateway support node) of GPRS in evolved 2G is responsible for establishing and managing the data connections between the mobile user and the destination network, SGSN in 3G is responsible for establishing the packet data protocol (PDP) context with the GGSN (gateway GPRS support node) upon activation.

Although GGSN in evolved 2G provides the point of attachment between the GPRS domain and external data networks, such as the internet and corporate intranets, GGSN in UMTS (3G) network is responsible for the internetworking between the GPRS network and the external packet-switched networks, for the billing, and allocates IP address to mobile users as well as provides other many functions. 3G technology offers a high level of security as compared to 2G technology because 3G networks permit validation measures when communicating with other services.

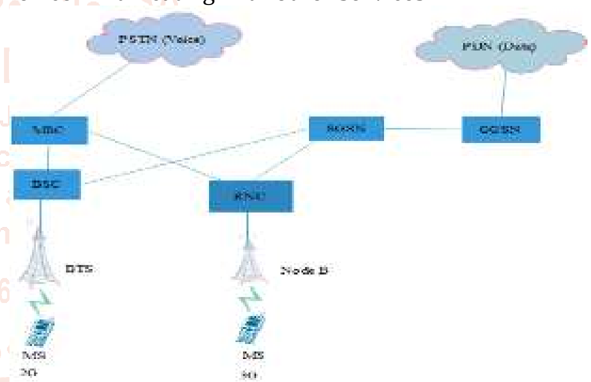

Fig 7: 2G and 3G Infrastructure

C. Evolution of 3G to 4G

ENode-B of 4G is the evolution of 3G Node-B with 3G radio network controller functionality. ENode-B provides security and better efficiency of operation by compressing these large IP headers compared to Node-B of 3G.

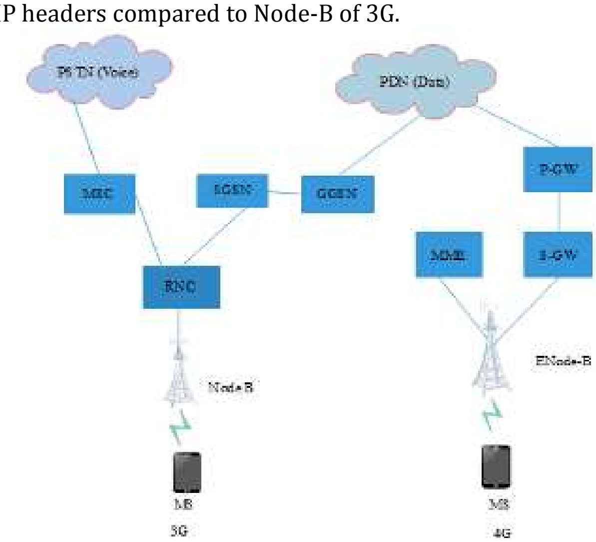

Fig 7: 3G and 4G Infrastructure

As shown in Fig 7,4G infrastructure contains different components as compared to 3G infrastructures. 3G uses the packet switching for data transmission but 4G uses both packet and message switching. In 4G, Hybrid network architecture is used while 3G uses a wide-area cell-based network. In 3G, CDMA (code division multiple access) is employed but 4G utilizes OFDMA (orthogonal frequency division multiple access). While handoff management is done vertically in 3G, 4G is done vertically as well as horizontally. Full IP Network is supported in 4G. However, in the case of 3G, it is circuit and packet-based. Essentially 4G promises to deliver even faster speeds than 3G but at an added cost of even less coverage (1km range) than 3G.

The author tabulates the comparison of Mobile generation infrastructure as shown in Table 1.

Table 1: Comparisons of 1G to 4G Infrastructures

Mobile Generations	BTS	BSC	MSC	SGSN	GGSN	S-GW	PDN-GW
1G	BTS, low number of user	-	MSC, routing for voice services	-	-	-	-
2G	BTS, high number of users	BSC, handles circuit switched	MSC, routing for voice and message services	-	-	-	-
2.5G	BTS, higher number of users	Besides BSC contains PCU, handles circuit and packet	MSC, routing for voice, message, and data services	Packet switched counterpart	Serves as a gateway for connect to data networks	-	-
3G	Node-B, more higher user, enhanced security and efficiency	RNC, handles circuit and packet switched	MSC, routing for voice, message, data and video services	Packet switched counterpart	Services as a gateway for connect to data networks	-	-
4G	Enode-B, most user, better security and efficiency	-	MME, routing for IP services	-	-	Serves packet filtering for user data	Provides gateway access to packet data networks

D. Fifth Generation Telephone Network (5G)

Fifth Generation (5G) is a generation currently under popular development. It denotes the major phase of mobile telecommunications standards beyond the current 4G standards. Facilities that might be seen with 5G technology includes far better levels of connectivity and coverage. The main focus of 5G will be on World-Wireless World Wide Web (www). It is a complete wireless communication with no limitations. In the service-oriented 5G network architecture, logical control functions can be abstracted as independent functional components, which can be flexibly combined according to service requirements. Logically decoupled from other components, network function components support neutral interfaced and implement an identical network interface message to provide services for other network function subscribers. A network function management framework provides network registration, identification, and management. Independent features ensure that the addition of network functions and potential upgrades do not affect existing network services. Creating and verifying 5G network based on 3GPP 5G New Radio standards poses development challenges for operators, vendors, and test equipment makers that that fall into seven broad categories: throughput, mobility, capacity, massive connectivity, latency and reliability, energy-saving and security [12].

E. Components of 5G Infrastructure

5G Infrastructure contains a radio access network (RAN), the core network (CN). RAN is referred to as Cloud RAN or cRAN, also known as the centralized RAN, is cheaper for operators in terms of capital expenditures and operating expenditures. However, it's still early in the cRAN development. A cRAN architecture has three primary components- a centralized baseband unit (BBU) pool, remote radio unit (RRU) networks, and transport network or front haul.

The BBU pool located at a centralized site functions as a cloud or a data center. Its multiple BBU nodes dynamically allocate resources to RRUs based on current network needs.RRU network: The wireless RRU network connects wireless devices similarly to access points or towers in traditional cellular networks. Front haul or transport network: Using optical fiber communication, cellular communication, or millimeter wave (mmWave) communication, the front haul is the connection layer between a BBU and a set of RRUs, providing high- bandwidth links to handle the requirements of multiple RRUs [8]. 5G core network will be able to utilize far greater levels of flexibility to enable it to serve the increased and diverse requirements placed upon it by the radio access network and the increased number of connections and traffic [7].

V. CONCLUSION

Mobile Communications are clearly going to show major enhancements in terms of capabilities of the mobile networks. The ever-growing demands for higher data rates, greater capacity and better quality of services triggered operators to come up with new network technologies. After studying, the author got knowledge of infrastructure developments in mobile generations. In the first generation (1G), the analogue system was introduced as the basic mobile voice services. 1G infrastructure contains components such as MS, BTS, MSC, and PSTN. The second-generation (2G) has fulfilled capacity and coverage enhancements. 2G infrastructure includes MS, BTS, base station controller (BSC), MSC, gateway MSC (GMSC), and

PSTN. 3G infrastructure composed of the user equipment (UE), Node-B, the radio network controller (RNC), MSC, serving gateway support node (SGSN), gateway GPRS support node (GGSN), PSTN, and PDN or internet protocol (IP). 4G infrastructure is upgraded in these portions, the UE, ENode-B, mobility management entity (MME), a serving gateway (S-GW), PDN gateway (P-GW) and PDN or IP. The last few years have experienced a remarkable growth in the wireless industry 5G technology going to be a new mobile revolution in the mobile market. The advent of 5G will revolutionize the field of communication domain, bringing wireless experience to a completely new level. The author hopes to become completely wireless, demanding uninterrupted access to information anywhere with better quality, high speed, increased bandwidth and reduction in cost.

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